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(54) A METHOD OF OPERATING AN AIRSHIP

(71) I, HERMANN PAPST, a citizen of the Federal Republic of Germany, of Karl-Maier-Strasse 1, St. Georgen, Schwarzwald, Federal Republic of Germany, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method of operating an airship of the type which employs methane, a hydrocarbon-containing gas and/or hydrogen both as lifting gas and also as the fuel for the power supply of the airship for the purpose to avoid the necessity of carrying additional solid or liquid fuels for generation of motion energy.

A proposal which has already been known for quite some time (Giffard 1855, Paris) concerns a steam-driven airship the lifting body of which is filled with illuminating (coal) gas. The proposal contemplates providing the heat for the steam engine with coal and compensating for the loss in weight which occurs as a result of the use of the coal by burning appropriate amounts of the lifting illuminating gas.

It has been also proposed (German Offenlegungsschrift 1,481,222) to consume natural gas in similar combination with Diesel oil for the power supply of the airship.

Another proposal contemplates using natural gas as buoyancy means and carrying water as additional ballast and vaporizing said water for compensation of the loss of buoyancy by burning the natural gas for power supply.

Due to this proposal, however, the additional water ballast reduces the lift of the airship from the beginning of a lift, thus also reducing the available lift for transport of goods.

In recently built dirigibles with helium or hydrogen as the lifting gas, to compensate for the loss in weight in liquid fuel resulting from the operation of the driving means, the water was condensed from the waste gases of the internal-combustion engine, in order to produce ballast and to reduce the lift and thus reduce the otherwise necessary draining of expensive helium or hydrogen. The actual lift available for transport purposes on a flight crossing the Atlantic was about 15 metric tons, while the weight of the fuel including the weight of the container for the fuel was about 60 metric tons.

As far as it is also known (Zeppelin LZ 127), to use gaseous fuel stored under high pressure conditions for combustion engines, such fuel is heavier than air and does not effect any positive effect on the buoyancy.

The purpose of the present invention is to eliminate the necessity of solid or liquid fuel and of any additional ballast, either. Thus, the airship of the invention is intended to avoid loss of free transport weight capacity or—from another view—can be built with reduced volume of buoyancy. Furthermore, it is another object of the invention to reduce the danger of fire by accidential burning of liquid fuel, which fuel normally would burn from the bottom of the airship while any used inflammable buoyant gas will burn over the head of any cabin in a direction less dangerous for passengers.

It is known from a photographic picture of the accident of the airship Hindenburg at Lakehurst in 1937 that some of the passengers were rescued because of this fact, while the rest of the passengers died because of the burning Diesel fuel flowing out of the destroyed fuel tanks after heavily touching the ground.

Inflammable gases when used in an airship are not as dangerous as generally believed, as long as such gases are under some pressure and are enclosed in a zone of non-inflammable protection gas which will act to quench flames should a fire start. The protection gas should have a low heat conductivity like carbon dioxide, nitrogen or argon and be under a somewhat greater pressure than the buoyant gas. Also by way of this increased pressure the envelope of the airship can be built double walled; reference is made to U.S. Patent 3,456,903.

This invention provides a method of operating an airship which comprises em-

ploying as both lifting gas and fuel supply stored in a first storage bag or bags, an inflammable lighter-than-air gas selected from hydrogen, methane and hydrocarbon-containing gas, generating power to drive said airship by consuming said inflammable gas, and employing as lifting gas at least a part of the product gas obtained by consumption of said inflammable gas. The product gas either by virtue of its molecular weight or by adjusting its temperature or pressure has at least the same total of buoyancy as the consumed inflammable gas, i.e. in this way it is possible to maintain the total lift of the airship constant or even to increase it, which also makes it possible for the buoyancy effect, which differs according to the flying elevation of the airship, to be adjusted or altitude-stabilized through use of correspondingly different portions of the product gas.

Such transformation can be accomplished by separating water from the exhaust gas obtained by burning natural gas, for instance, while driving combustion engines, heating apparatus or even steam generating apparatus and re-heating and re-vaporizing said water, preferably by use of the excess heat of said converting means. The generated steam, then, is transferred to the buoyancy chambers of the airship.

Natural gas can be employed in the method according to the invention by reacting it in the presence of water vapor in order to produce hydrogen gas to be employed partly for compensation of buoyancy and partly for the operation of fuel cells or other electric means. This reaction [see equation (3) below[can be performed to generate hydrogen before take off, as well as during the flight.

By using the method according to the invention, the total buoyancy of the airship per unit of weight to be transported can be surprisingly reduced because any additional lifting force for the motion fuel is avoided. Also the weight of the fuel containers is not present any more. Thus, the overall volume of the airship of the present invention depends only on the weight of its specific construction and on the desired capacity for transport weight.

If, for example, we proceed from the combustion of methane heated to 100°C by way of saturated water vapor contained in chambers contacting the cells containing the methane, and if we replace step by step its lifting volume having a lifting force of 0.77 kg/m^3 in air at 0°C by water vapor of approximately the same temperature having a lifting force of 0.695 kg/m^3, then we require for constant lift for 1 volume of methane approximately one quarter more of water vapor. For replacement of the natural gas by water vapor with respect to constant lifting force only about 62.5% of the water component gained by burning the natural gas is needed. In replacing the volume of natural gas, the water vapor, by way of its one-quarter excess volume, replaces also a corresponding volume of heated air from additional compensation cells. This heated air which is displaced, has for instance a temperature of 100°C and a lifting force of 0.35 kg/m^3. The resulting loss of lift increases because of expansion of the air with increased altitude of the flight, and the airship maintains a definite altitude. With increasing replacement of air by vapor, the lifting force increases, and *vice versa*. Thus, in order to stabilize the altitude of the flight, the lift of inflammable gas which has been consumed is partly replaced by water vapor, whose increased volume leads to displacement of a corresponding volume of warm air contained in additional compensation cells.

The delivery of warm air from the compensation cells, which delivery, depending on the mere expansion of the gases with increased altitude, is about 10% per kilometre, has to be restored if the airship decreases. In order to perform a stabilized flight without dropping ballast weight this restoration of lifting force is accomplished by taking into the compensation cells an adequate amount of air and heating it up to for instance 100°C, for which heating preferably the excess heat of the combustion engines is used.

Furthermore, according to the invention it is contemplated to employ a portion of the hydrogen produced by reaction of the buoyant natural gas according to equation (4) below after removing the carbon dioxide for oxidation in fuel cells to generate electric power by means of which electric motors of the main blowers for driving the airship, and those driving auxiliary equipment, is supplied. If the electrically driven blowers are equipped for normal flight speed, in time of top power circumstances additional combustion engines can be used.

The necessary power for driving the airship can be remarkably additionally reduced if the principle of removing the boundary layer by suction is applied or the outer surface of the airship is covered by a foil of aluminium having a hydrophobic surface layer of fluoro carbon resins (see British Patent Specification No. 1,191,322) which layer keeps the air flow along the airship in laminar condition and the friction low. By use of these principles the consumption of natural gas for driving purposes is reduced and an adequate excess volume of the buoyancy can be filled with other buoyant gases, like for instance helium or hydrogen, which do not need to be changed or converted.

The method according to the invention can also be performed if the saturated steam has another temperature than the natural gas. For instance, the lifting force of natural gas

at a temperature of 57°C is the same as that of water vapor at 100°. Under such conditions, the volume of the natural gas to be replaced by vapor is the same as of the vapor, and it is no longer necessary to remove an excess of warm air from the compensation cells in the course of substituting water vapor for natural gas, constant altitude provided. By way of this effect the interchangeability of the gases can be controlled over a wide range of temperature and the energy of the gases can be used more effectively.

By conversion of 1 mol of methane, aside from the carbon dioxide, the volume of the produced water-component is twice the methane volume (2 mol) due to the equation.

$$CH_4+2O_2=CO_2+2H_2O \quad (1)$$

The carbon dioxide component can be frozen out, although its effect on the lifting force is only about 10% of the hydrogen or water vapor heated at 100°C being contained in the buoyancy chambers. Thus, separation of the carbon dioxide is not necessary and any additional equipment can be omitted.

In the preferred embodiment of the method according to the invention, the natural gas or any other hydrocarbon gases gained from natural oil, especially methane, is converted in the presence of water vapor by partial oxidation in a suitable reactor into gaseous hydrogen, whereby an increased volume of gas is achieved. This conversion is performed by two main steps of the following reactions which are in general already known from the production of synthetic fertilizers:

$$\begin{array}{l} CH_4+H_2O=CO_2+3H_2 \quad (2a) \\ CO\ +H_2O=CO_2+H_2 \quad (2b) \\ \hline CH_4+2H_2O=CO_2+4H_2 \quad (3) \end{array}$$

For performance of reaction (3) rain water collected from the outer surface of the airship can be used.

The necessary water can be obtained also from the combustion products of natural gas burnt in a suitazle reactor e.g. an internal combustion engine or a heating or steam-generating apparatus, along (1) of the following reactions:

$$\begin{array}{l} CH_4+2O_2=CO_2+2H_2O \quad (1) \\ CH_4+2H_2O=CO_2+4H_2 \quad (3) \\ \hline 2CH_4+2O_2=2CO_2+4H_2 \quad (4) \end{array}$$

Thus, the lifting force of 1,5 kg of the consumed 2 m^3 CH_4 having a temperature of 100°C the produced 4 m^3 H_2 at 100°C have a lifting force of 4,9 kg after reduction by the weight of 0,4 kg of the produced 2 m^3 CO_2 (at 100°C). The gained new lifting force after conversion of the gases is about: 4,5 kg−1,5 kg=3 kg. Due to the remarkable increase of lifting force two third of the produced hydrogen may be used for other than buoyant purposes. According to reaction (4) by the use of water vapor which is already employed in the airship as buoyant gas a new lifting force of 2,75 kg is gained.

This transformation which is given in the example and which occurs primarily in natural gas (i.e., the transformation of methane) is similarly valid for other hydrocarbons according to the invention, for example:

$$\begin{array}{l} C_8H_{18}+8H_2O=8CO+17H_2 \quad (5) \\ 8CO+8H_2O=8CO_2+8H_2 \quad (6) \\ \hline C_8H_{18}+16H_2O=8CO_2+25H_2 \quad (7) \end{array}$$

The supply for reaction (7) can be performed by taking up a storage of gaseous hydrogen at a natural oil well. Similar to the conversion of methane the reactions (5), (6) and (7) can be performed in presence of catalysts, for instance chromium oxide and zinc oxide or nickel oxide.

The saturated water vapor serves as a supply source for heating the buoyant gases substantially constantly at or close to 100°C whereby the vapor is partly condensed. By heating the gaseous hydrogen the increase of lifting force is only 27 g/m^3, however, the volume of the hydrogen increases 1,367 times. Thus, one cubic metre having a weight of 0,089 kg at 0°C after being heated to 100°C is able to substitute 1,767 kg air (1,367×1,293=1,767 where the air density is 1,293 kg/Nm^3) and the increase of lifting force resulting from that hydrogen replacing the air is from 1,21 kg to 1,678 kg at height above sea level (760 mm air pressure).

Due to the consumption of water according to the abovementioned reaction (3) an additional amount of lifting force is obtained and the overall increase in lifting force by conversion of one cubic metre natural gas at 100°C is even (4×1,23)+(2×0,598)−0,77 =5,34 kg, without consideration of the carbon dioxide.

The necessary heat consumption for the abovementioned reaction (3) is preferably covered by the excess heat of the combustion engines.

It has to be mentioned that by use of the saturated water vapor the buoyant gases can be maintained even at a less high temperature if the saturated water vapor is mixed with other gases. In such mixtures of gases the partial pressure of the saturated water vapor can be varied. For instance at a partial pressure of 92,5 mm mercury column the saturated condition of the water vapor exists at a temperature of 50°C.

The main advantage of the method according to the invention is that the buoyant gas can be used for driving the airship without need for any solid liquid fuel or additional ballast to compensate the consumption of the buoyant gas. Consequently the airship operated in accordance with the invention can have a remarkably reduced overall volume or an adequately increased capacity of lifting force available for transport purposes.

An airship utilizing the invention is shown by way of example in the accompanying drawings, in which Fig. 1 is a schematic elevation view of the airship having several separate chambers within its body and a frame structure within which all necessary equipment is installed as illustrated by way of an enlarged schematic flow diagram, and Fig. 2 is a partial view of the flow diagram which view in particular refers to the catalyzer reactor means.

The reference numerals shown in Fig. 1 designate the following features:

1 is a double walled outer envelope preferably as described in U.S. Patent 3,456,903.

3a, 3b and 3c are separating walls which are invertable and invaginating within envelope 1, i.e. they can be turned inside out and are preferably made of flexible material. Individual walls thereof can also be constructed as being heat insulating.

41 are separate chambers containing cold (2°C) or heated air alternatively and being used as compensation cells and having an inlet-outlet connection 41a. 43 are separate chambers containing water vapor at saturated conditions (100°C) at least near the walls and having an inlet-outlet connection 43a.

45 is a storage chamber for protective gas to be preferably used for filling the space between the two walls of the double walled envelope 1, the chamber having an inlet-outlet connection 45a. The protective gas can be carbon dioxide and/or nitrogen and air, such gases being preferably without any considerable moisture portion.

37 are separate chambers for gases, preferably buoyant gases like natural gas, or pure methane (alternatively also gaseous hydrogen can be stored in these chambers); the chambers 37 having an inlet-outlet connection 37a.

39 is a center chamber containing buoyant gas in general, i.e. gaseous hydrogen or other buoyant gases including mixtures of gases alternatively containing water vapor. The center chamber has inlet-outlet connections 39a and 39b.

49 are controlled inlet check valves.

51 are biased outlet check valves.

35 is water vapor producing apparatus.

47 are exhaust or waste gas pipes.

25 is a blower for moving the protective gas and maintaining the gas pressure within the envelope space, driven by electric motor 25a.

27 is a blower for moving the air into chambers 41, driven by electric motor 27a.

31 is an auxiliary blower for propelling the airship under slow speed conditions.

33 is a main blower preferably driven by a combustion engine or a turbine engine, which main blower drives the airship by forcing air through connection 34 and channel 15 to the jet at the rearward end 7 of the airship.

24 is an electric control center.

60 is catalyst apparatus for converting the natural gas into gaseous hydrogen.

23 is apparatus containing a hydrogen-supplied fuel cell system along with an accumulator station for storing electrical power.

55 is heat interchanging apparatus (connections not shown) for employing the heat of water vapor from chamber 43 to heat air being driven into chamber 41 by blower 27.

57 is apparatus for condensing water vapor, preferably from waste gas.

11 is main airjet having an annular nozzle 9 for driving the airship by air propulsion, which jet is supplied by channel 15 from main blower 33 as disclosed in U.S. Patent 3,456,909.

13 is a tail plane with steering vanes 13a.

61 is means for controlling speed and power of the electric motors.

According to schematically drawn Fig. 2 the heat liberated by the catalytic conversion of natural gas or methane to gaseous hydrogen can be used for pre-heating or heating water to produce water vapor. This can be accomplished preferably simultaneously by interchange of the heat of the waste gas. This can be carried out using catalyst apparatus 60. Inflammable gas from chamber 37 and water vapor from chamber 43 are led to catalyst apparatus 60, where they are reacted and the product gas is conducted to centre chamber 39. Exhaust gas in pipe 47 from main blower 33 is passed through apparatus 60 where it is heated by heat of reaction and is then passed to condenser 57 to condense out water vapour.

Any waste or exhaust gas can be conducted to channel 15 and by this means utilised as driving energy for the airship.

WHAT I CLAIM IS:—

1. A method of operating an airship which comprises employing as both lifting gas and fuel supply stored in a first storage bag or bags, an inflammable lighter-than-air gas selected from hydrogen, methane and hydrocarbon-containing gas, generating power water vapour which is stored in a heat-inflammable gas, and employing as lifting gas at least a part of the product gas obtained by consumption or said inflammable gas.

2. A method as claimed in Claim 1 wherein the inflammable gas contains a hydro-

carbon, the product gas is water vapour, hydrogen, or a gas containing water vapour or hydrogen, and at least a portion of said product gas is fed to and stored in a second storage bag or bags.

3. A method as claimed in Claim 1 wherein the inflammable gas is burnt to provide heat of combustion and a combustion gas including water vapour, said water vapour is condensed, and at least a portion of said condensed water vapour is evaporated by said heat of combustion to form reconverted water vapour which is stored in a heat-insulated storage bag or bags separate from said first storage bag or bags.

4. A method as claimed in Claim 1 wherein the inflammable gas contains a hydrocarbon and is catalytically converted in the presence of water vapour into hydrogen, carbon monoxide and carbon dioxide.

5. A method as claimed in Claim 1 wherein said product gas comprises hydrogen, which is employed in a fuel cell to generate electricity which is employed in a blower to drive said airship.

6. A method as claimed in Claim 1 or 5 wherein the inflammable gas is methane or natural gas which is consumed according to the reaction

$$CH_4+2H_2O=CO_2+4H_2.$$

7. A method as claimed in Claim 1 wherein said inflammable gas contains a hydrocarbon and a portion of said hydrocarbon is reacted chemically before take off to generate hydrogen and/or water vapour.

8. A method as claimed in Claim 1 substantially as hereinbefore described.

MICHAEL BURNSIDE & COMPANY,
Chartered Patent Agents,
36 Westminster Palace Gardens,
Artillery Row,
London, SW1P IRR.
Agents For The Applicants.

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1348408 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

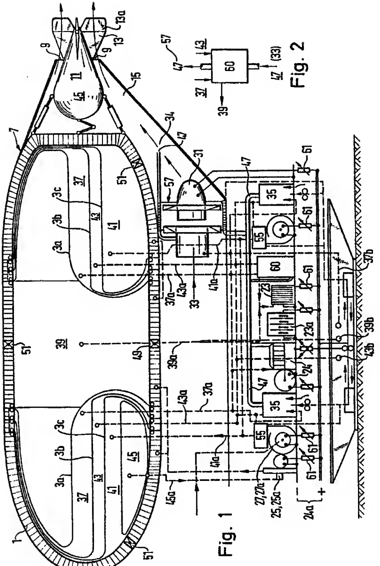

Fig. 1

Fig. 2